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[54] **SPARK DURATION CONTROL FOR A CAPACITOR DISCHARGE IGNITION SYSTEM**

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[51] **Int. Cl.**[5] **F02P 5/145**; F02P 3/045; F02P 3/08

[52] **U.S. Cl.** **123/605**; 123/609; 123/623; 123/644; 123/643

[58] **Field of Search** 123/596, 605, 609, 620, 123/623, 634, 643, 644

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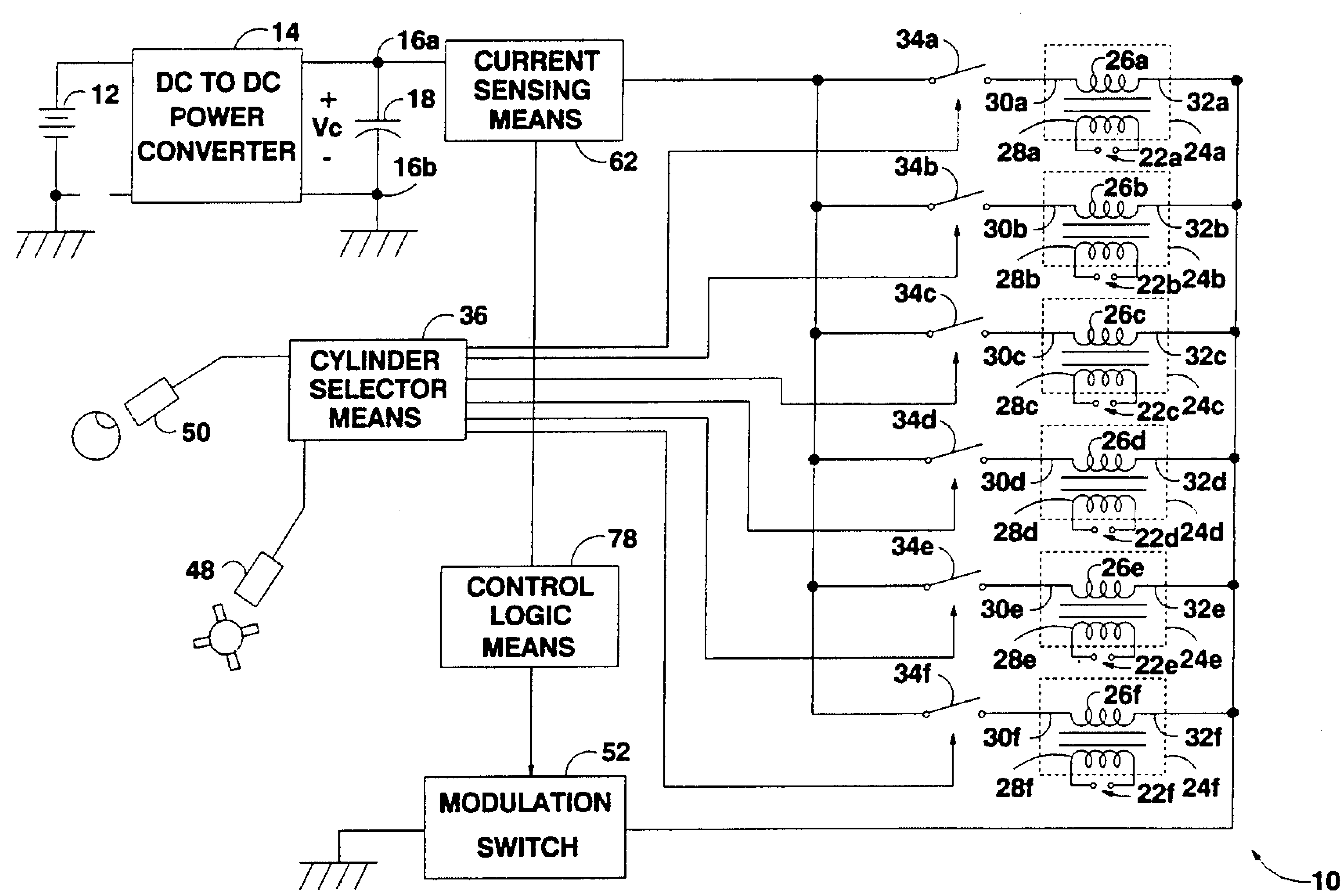
[57] **ABSTRACT**

An apparatus is provided for controlling ignition in an internal combustion engine having N cylinders and a capacitor discharge ignition system. The capacitor discharge system includes an ignition capacitor which is maintained at a predetermined electrical potential by a charging circuit. N transformers are provided, each having a primary coil and a secondary coil. The primary coils include first and second terminals and the secondary coils are electrically connected in parallel with the spark gap in an associated one of the cylinders. Selector switches are connected between the ignition capacitor and an associated one of the primary first terminals. The selector switches are normally biased open and are adapted to close in response to receiving cylinder select signals. The cylinder select signals are produced in response to a desired ignition sequence and for a period of time corresponding to a desired spark duration in an associated cylinder. A modulation switch is connected between the primary coil second terminals and a source of low electrical potential. Control circuitry is provided for operating the modulation switch while a selector switch is closed such that the current flowing in an associated primary coil initially rises to a first threshold sufficient to cause a spark to arc an associated spark gap. Thereafter the current is modulated between the first threshold and a second threshold lower than the first threshold to maintain the spark. The spark is maintained in this manner until the associated selector switch is opened.

12 Claims, 4 Drawing Sheets



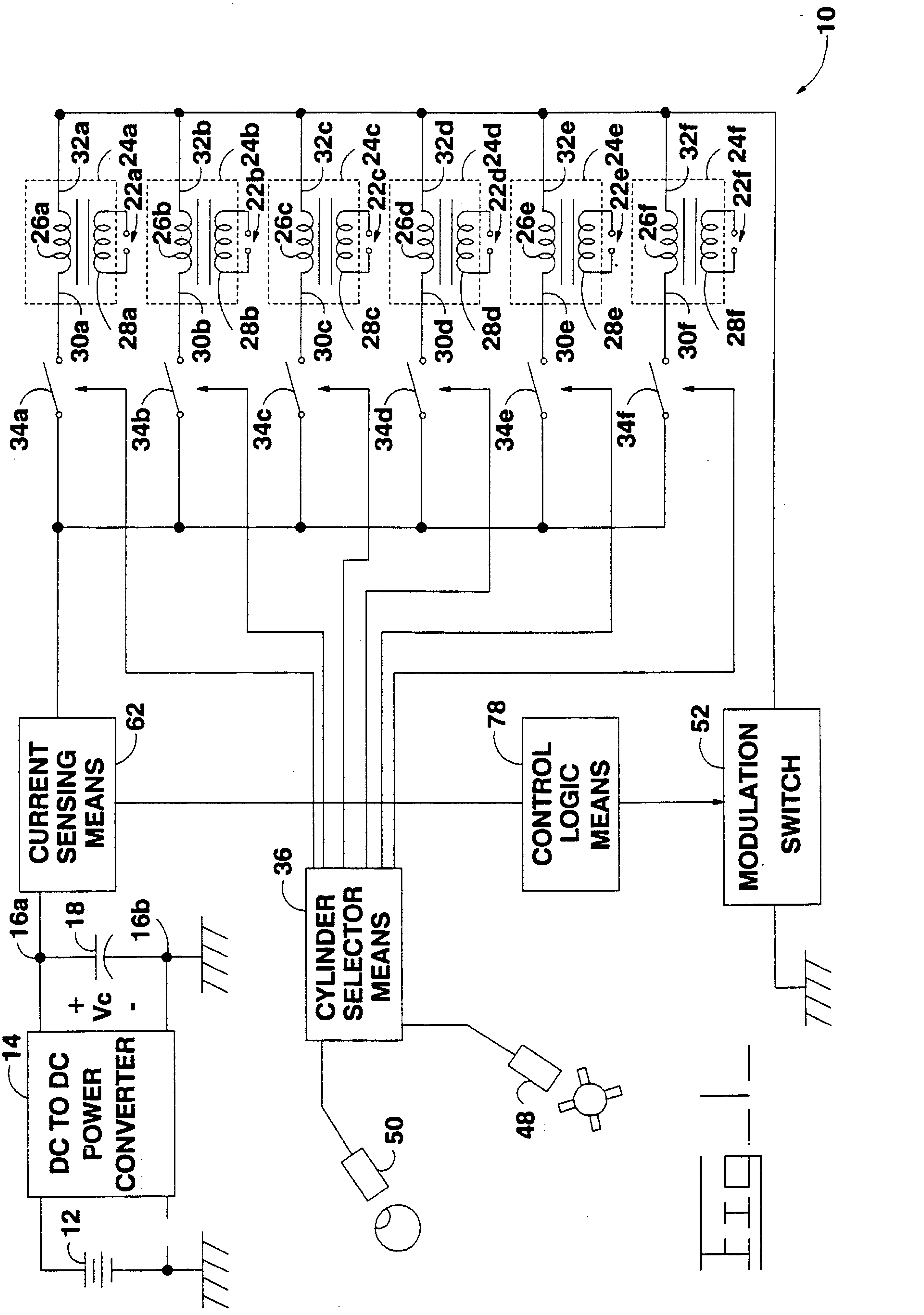
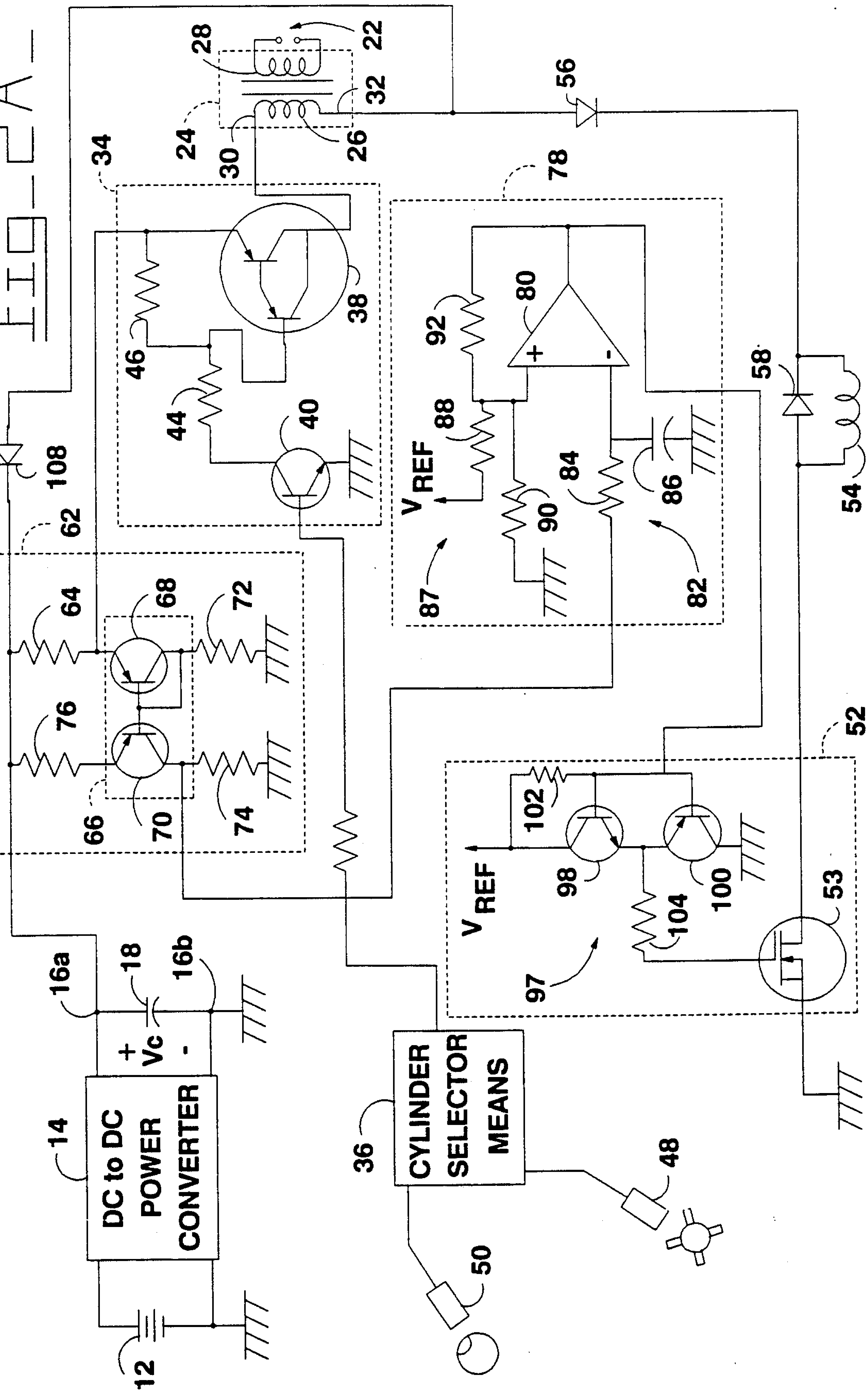

DC TO DC POWER CONVERTER
CURRENT SENSING MEANS
CYLINDER SELECTOR MEANS
CONTROL LOGIC MEANS
MODULATION SWITCH
Vc

FIG. 1



DC to DC POWER CONVERTER
CYLINDER SELECTOR MEANS
V_{REF}
V_{REF}
+ Vc -

FIG. 2A

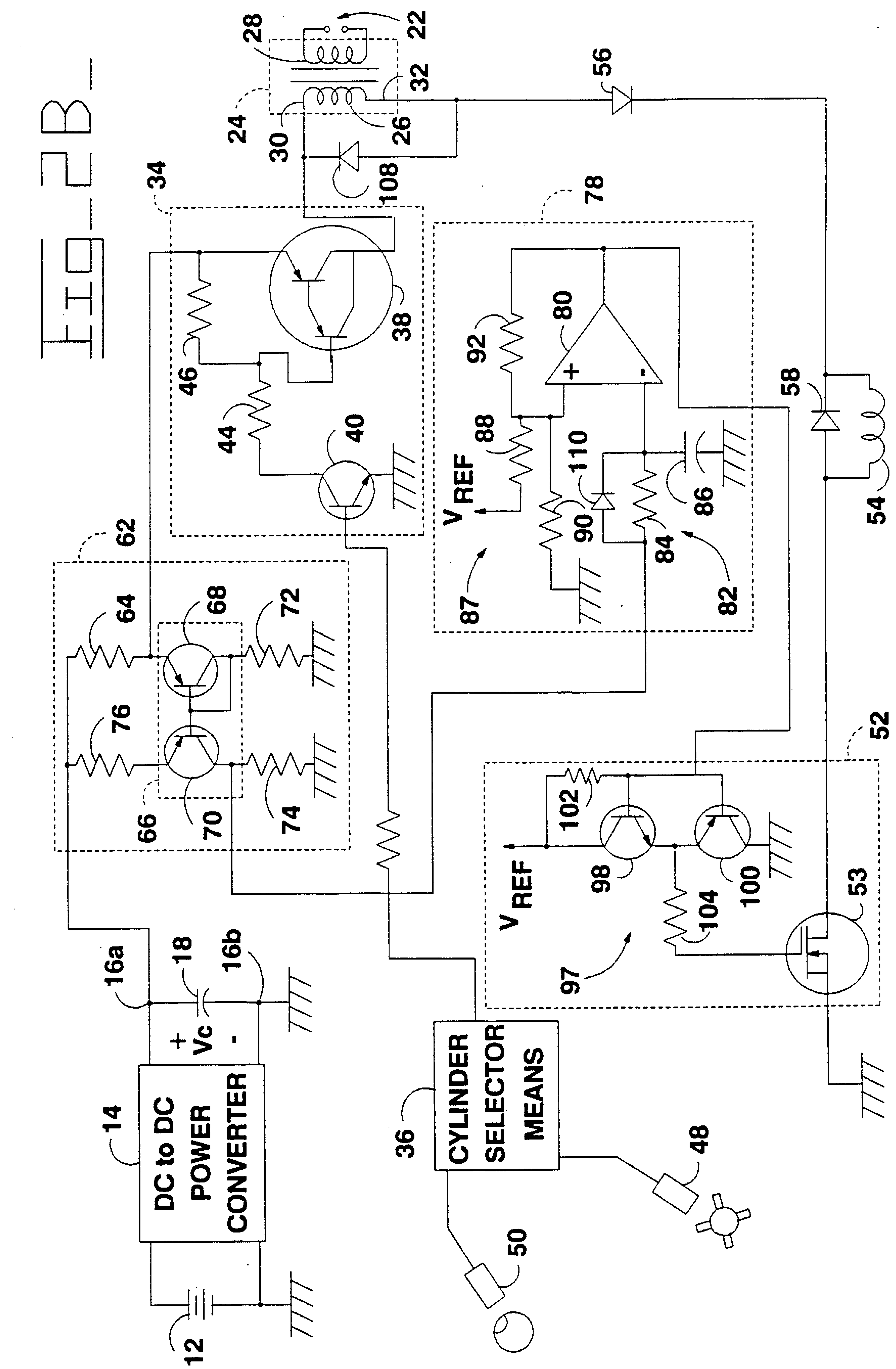

DC to DC
POWER
CONVERTER
CYLINDER
SELECTOR
MEANS
VREF
VREF
+
Vc
-

FIG. 2B

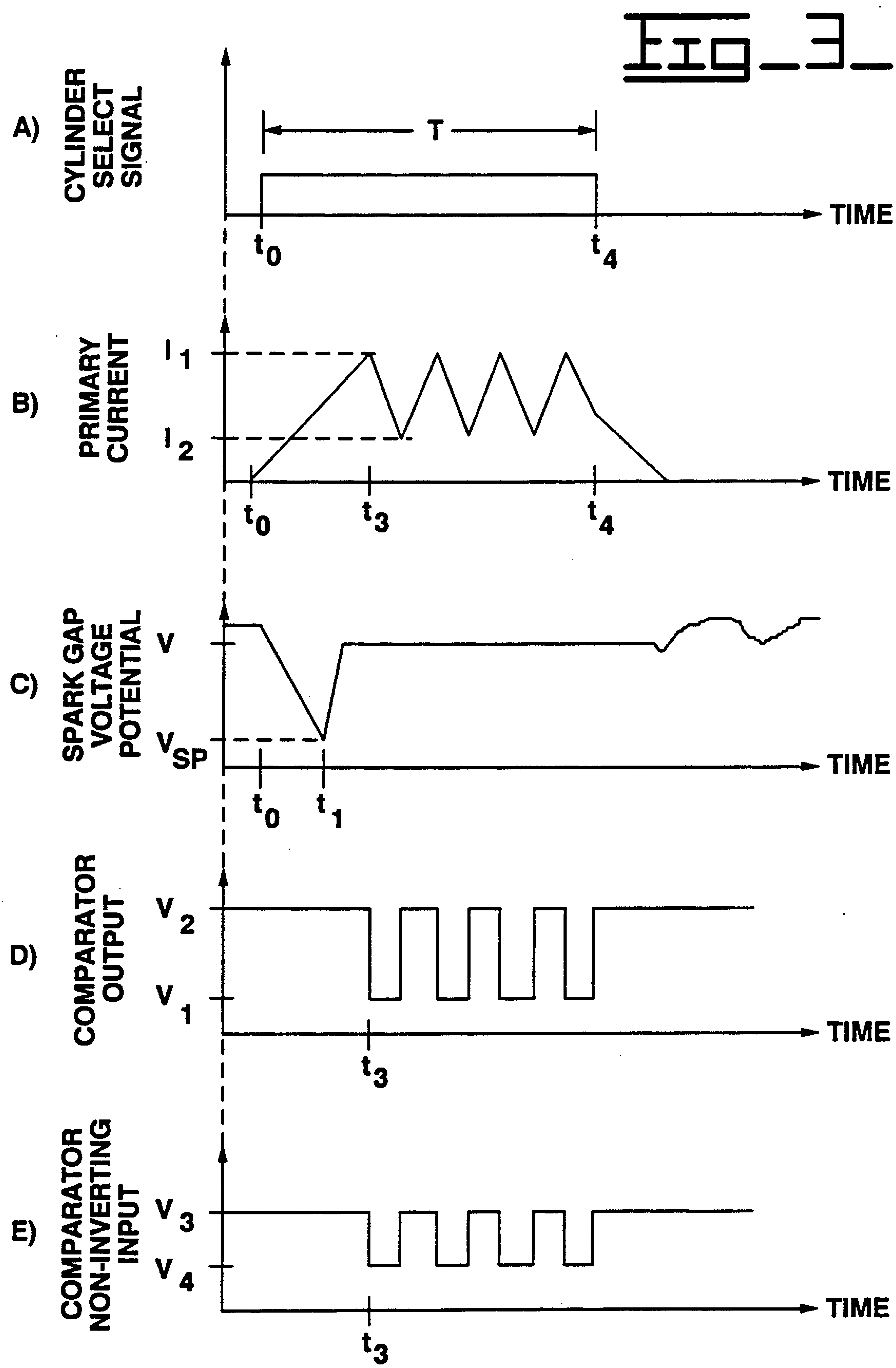


Fig_3_
A) CYLINDER SELECT SIGNAL
T
TIME
t0
t4
B) PRIMARY CURRENT
I1
I2
TIME
t0
t3
t4
C) SPARK GAP VOLTAGE POTENTIAL
V
VSP
TIME
t0
t1
D) COMPARATOR OUTPUT
V2
V1
TIME
t3
E) COMPARATOR NON-INVERTING INPUT
V3
V4
TIME
t3

SPARK DURATION CONTROL FOR A CAPACITOR DISCHARGE IGNITION SYSTEM

DESCRIPTION

1. Technical Field

This invention relates generally to a capacitor discharge ignition system for an internal combustion engine and, more particularly, to a system for controlling spark duration in a capacitor discharge ignition system.

2. Background Art

Capacitor discharge ignitions (CDI's) are well known in the art. Typically, CDI's include a charge storage mechanism, such as a capacitor, and a step-up transformer with a secondary connected to a spark ignition device, such as a spark plug. A mechanism is provided to discharge the capacitor through the transformer primary coil in timed relationship with a desired engine ignition sequence. The discharge of the capacitor through the transformer primary coil induces a high voltage signal in the transformer secondary coil, which, if sufficiently high, causes a spark to arc across the spark plug gap. More specifically, the voltage applied across a spark ignition device must be greater than or equal to a predetermined characteristic "spark ionization potential" (voltage) in order to initiate the spark. Such ionization potentials are typically on the order of 10 Kv or more. However, once the spark has been initiated, the spark can be sustained by a maintaining a substantially voltage potential across the spark plug gap. Typically this lower voltage potential is on the order of 1 Kv or less.

It is desirable to be able to extend the spark duration to ensure full combustion of the air/fuel mixture in the cylinder. However, past CDI's have suffered from the inability to maintain spark duration for any significant amount of time. This is because CDI's typically use the full capacitor charge to initiate the spark and, therefore, no charge exists for maintaining or extending the spark's duration.

One system which recognize this problem is disclosed in U.S. Pat. No. 3,832,986 which issued on Sept. 3, 1974 to Dogadko. The Dogadko patent discloses a CDI system which includes a main capacitor for establishing the spark and a second capacitor for extending the spark's duration. A fist SCR is triggered to discharge the first capacitor through the ignition primary to establish the spark. A timer means is operative in response to discharge of the main capacitor for triggering a second SCR to discharge the second capacitor through the primary at a predetermined period of time after discharge of the main capacitor, thereby extending the spark. However, the Dogadko system has additional costs associated with the additional capacitors and SCR's. Therefore, it is desirable to provide a CDI which does not require these additional components and has the ability to control spark duration.

The subject invention is directed toward addressing one or more of the problems as set forth above.

DISCLOSURE OF THE INVENTION

An apparatus is provided for controlling ignition in an internal combustion engine having N cylinders and a capacitor discharge ignition system. The capacitor discharge system includes an ignition capacitor which is maintained at a predetermined potential by a charging circuit. A plurality of transformers are provided, each having a primary coil and a secondary coil. Each primary coil includes first and second terminals and each secondary coil is electrically connected in parallel with a spark gap in an associated one of the cylinders. Selector switches are connected between the ignition capacitor and an associated one of the primary first terminals. The selector switches are normally biased open and are adapted to close in response to receiving cylinder select signals. The cylinder select signals being produced in response to a desired ignition sequence and for a period of time corresponding to a desired spark duration in an associated cylinder. A modulation switch is connected between the primary coil second terminals and a source of low electrical potential. Control circuitry is provided for operating the modulation switch while a selector switch is closed such that the current flowing in an associated primary coil initially rises to a first threshold sufficient to cause a spark to arc an associated spark gap. Thereafter the current is modulated between the first threshold and a second threshold lower than the first threshold to maintain the spark. The spark is maintained in this manner until the associated selector switch is opened.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an illustrative block diagram of an embodiment of the immediate capacitor discharge ignition system;

FIG. **2A** is circuit diagram of an embodiment of the system of FIG. **1**;

FIG. **2B** is a circuit diagram of an alternate embodiment of the system of FIG. **1**; and

FIGS. **3A–E** are graphic illustrations of certain waveforms associated with the embodiments of FIGS. **1, 2A** and **2B**.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to the drawings, the immediate capacitor discharge ignition system **10** will be discussed. FIGS. **2A** and **2B** are circuit diagrams for realizing alternate embodiments of the immediate CDI system **10**. The same reference numerals have been used for like components in FIGS. **2A** and **2B**. For simplification, FIGS. **2A** and **2B** have been illustrated in connection with a single engine cylinder. However, the system **10** will work with an internal combustion engine having any any number of cylinders provided electrical components are sized properly. Therefore, FIG. **1** is described in connection an engine having six cylinders. Throughout the description of the system **10** reference will be made to certain electrical waveforms illustrated in FIGS. **3A–F**.

The system **10** includes a power source **12**, such as a battery, connected to a DC-to-DC power converter **14**. The power converter **14** is a continuously operating, high speed charging circuit and it is electrically connected to first and second terminals ***16a, 16b*** of an ignition capacitor **18**. The power converter **14** is provided for rapidly charging the ignition capacitor **18** and continuously supplying power to the capacitor **18** to maintain the capacitor first terminal ***16a*** at a predetermined electrical potential above the capacitor second terminal ***16b***. More particularly, the capacitor second terminal ***16b*** is connected to system ground and the first terminal ***16a*** is maintained a preselected potential V_c above system ground. In the preferred embodiment, the preselected potential V_c is on the order of 200 volts. Converters of this type are common in the art and, therefore, will not be explained in greater detail. One such circuit is generally disclosed in U.S. Pat. No. 3,677,253 which issued on July 18, 1972 to Oishi et al.

Each engine cylinder (not shown) includes a spark plug (not shown) having an associated spark gap **22***a–f*. Step-up transformers **24***a–f* are provided for each cylinder to control operation of an associated spark plug. Each transformers **24***a–f* has a primary coil **26***a–f* and a secondary coil **28***a–f*. The transformer primary coils **26***a–f* each include first and second terminals **30***a–f*, **32***a–f*. The transformer secondary coils **28***a–f* are electrically connected in parallel with a spark gap **22***a–f* in an associated one of the engine cylinders.

Selector switches **34***a–f* are connected between the ignition capacitor first terminal **16***a* and an associated one of the primary coil first terminals **30***a–f*. The selector switches **34***a–f* are normally biased open and are adapted to close in response to receiving a cylinder select signals (See FIG. 3A) from a cylinder selector means **36**. Each selector switch includes a darlington-type transistor **38** having an emitter connected to the the ignition capacitor first terminal **16***a* and a collector connected to an associated primary coil first terminals **30***a–f*. It should be apparent that suitable alternatives could be used in place of the electrical components described without departing the scope of the applicant's invention. For example, numerous alternative switches could be used in place of the darlington-type transistor **38**. A first npn transistor **40** has a base connected to the cylinder selector means **36**. The transistor's base is adapted to receive the selector signal. The first npn transistor **40** further has an emitter connected to system ground and a collector connected to the base of the darlington-type transistor **38** through a first resistor **44**. A second resistor **46** is connected between the junction of the first resistor **44** and the darlington-type transistor's base and the junction of the ignition capacitor first terminal **16***a* and the darlington-type transistor's collector. The first npn transistor **40** is biased "on" when the cylinder select signal is applied to its base. This establishes a base current path for the darlington-type transistor **38** which biases the darlington-type transistor **38** "on." When the darlington-type transistor **38** is biased "on", the ignition capacitor first terminal **16***a* and the primary coil first terminal **30***a–f*, of an associated transformer **24***a–f*, are electrically connected, thereby establishing a current path through the primary coil **26***a–f*.

The cylinder selector means **36** is provided for operating the selector switches **34***a–f* in a timed sequence corresponding to a desired ignition sequence for the engine. The cylinder selector means **36** receives signals corresponding to engine speed and cylinder position from engine speed and sensor **48** and a cylinder position sensor **50**, respectively. Such sensors are common in the art and, therefore, will not be explained in detail. The function of the sensors **48, 50** could be performed using a single sensor such as that disclosed in U.S. Pat. No. 4,972,323 which issued on Nov. 20, 1990 to Luebbering et al. and is assigned to the assignee herein. The cylinder selector means **36** processes these signals to produce cylinder select signals for controlling operation of the select switches **34***a–f*. The cylinder select means **38** produces the cylinder select signals for a period of time corresponding to the desired spark duration in an associated cylinder. The desired spark duration can be a constant period of time or it can be adjusted in response to sensed engine parameters. The duration that the cylinder select signal remains high corresponds to a desired spark duration T. During this period, the selector switch **34***a–f*, to which the selector signal is delivered, remains closed.

A modulation switch **52** is connected between the primary coil second terminals **32***a–f* and system ground for completing a current path for the primary coils **26***a–f*. When a cylinder select switch **34***a–f* and the modulation switch **52** are closed current begins to flow from the ignition capacitor **18** through the associated primary coil **26***a–f*. The modulation switch **52** includes an n-channel MOSFET **53** having a drain connected to the primary coil second terminals **32***a–f* through an inductor **54** and a first diode **56**. The inductor **54** is provided to limit current changes at the MOSFET drain. The MOSFET **53** further has its source connected to system ground. A second diode **58** has a cathode connected to the junction of the inductor **54** and the first diode **56** and an anode connected to the junction of the inductor **54** and the n-channel MOSFET **53**. The second diode **58** is provides a flyback path for the inductor **54** to limit voltage spikes caused by the inductor **54** when the n-channel MOSFET **53** opens.

The MOSFET **53** is biased "on" when a "high" logic signal is applied to its gate. When this occurs, the primary coil second terminals **32***a–f* are connected to system ground, thereby establishing a current path for the primary coil **26***a–f* having a "closed" selector switch **34***a–f*.

A current sensing means **62** senses the current flowing through any of the transformer primary coils **26***a–f* and responsively produces a primary current signal. The current sensing means **62** includes a first current sensing resistor **64** connected between the selector switches **34***a–f* and the ignition capacitor first terminal **16***a*. A current mirror circuit **66** is connected to the first current sensing resistor **64** such that the current flowing through the resistor **64** is an input to the current mirror circuit **66**. The current mirror circuit **66** delivers an output current signal which has a magnitude responsive to the magnitude of the current flowing through any of the primary coils **26***a–f*. Only one current mirror circuit **66** is required since only one of the cylinder select switches **34***a–f* is closed at any given instance in time.

The current mirror circuit **66** includes first and second pnp transistors **68, 70** wherein both transistors **68, 70** have bases connected to the other and to the collector of the first transistor **68**. The collectors of the transistors **68, 70** are further connected to system ground through third and fourth resistors **72, 74**, respectively. The emitter of the first pnp transistor **68** is connected to the ignition capacitor first terminal **16***a* through the first current sensing resistor **64**. The emitter of the second pnp transistor **70** is connected to the ignition capacitor first terminal **16***a* through a second current sensing resistor **76**. As would be apparent to one skilled in the art, selection of the ohmic values of the first and second current resistors **64, 76** controls the relationship between the input and output of the current mirror circuit **66**.

The output of the current mirror is delivered to a control logic means **78** which produces first and second control signals in response to the current mirror output signal. The first and second control signals are applied to the modulation switch **52** to respectively open and close the modulation switch **52**. More specifically, the control logic means **78** produces an output signal which switches between first and second voltage potentials

V1, V2 (see FIG. 3D). When the signal is at the first potential V1 corresponding to logic "low," the modulation switch 52 is biased open. Conversely, when the signal is at the second potential V2 corresponding to logic "high," the modulation switch 52 is biased closed. The control logic means 78 operates the modulation switch 52 while a selector switch 34*a–f* is closed such that the current flowing in an associated primary coil initially rises to a first current threshold I1 which is sufficient to cause a spark to arc an associated spark gap 22*a–f*. Thereafter, the spark is maintained by modulated the current in the primary coil 26*a–f* between the first current threshold I1 and a second current threshold I2 which is lower than the first current threshold I1. The current flowing through the primary coil 26*a–f* is shown in FIG. 3B and the voltage across and associated spark gap 22*a–f* is shown in FIG. 3C. The second current threshold I2 is selected to be of a magnitude sufficient to ensure that a spark is sustained across the spark gap 22*a–f*. In this manner, the charge dissipated from the ignition capacitor 18 is minimized, thereby avoiding the problems associated with past capacitor discharge ignitions. More specifically, by limiting current flow from the ignition capacitor 18, the immediate CDI system 10 is capable of maintaining spark duration over a wide range of engine speeds while only requiring a single ignition capacitor for a plurality of engine cylinders.

The control logic means 78 includes an open-collector comparator 80 having an inverting input terminal adapted to receive the current mirror output signal. The comparator inverting input terminal is connected to the junction of the second pnp transistor 70 and the fourth resistor 74 through an R-C network 82. The current output from the current mirror circuit 66 establishes a voltage across the fourth resistor 74 which is applied to the comparator inverting input terminal. As should be apparent, this voltage is proportional to the current flowing through the first current sensing resistor 64 and thus to the current in the primary coil 26*a–f*. The R-C network 82 includes a fifth resistor 84 serially connected between the junction of the second transistor's emitter and the fourth resistor 74 and comparator inverting input terminal. The R-C network 82 further includes a first capacitor 86 connected between the junction of the fifth resistor 84 and the comparator inverting input terminal and system ground.

The non-inverting input terminal is connected to a voltage divider network 87 for controlling the voltage level applied thereto. More particularly, the non-inverting input terminal is connected to a preselected reference potential V_{ref} through a pull-up resistor 88 and to system ground through a sixth resistor 90. The non-inverting input terminal is further connected to the output terminal of the comparator 80 through a seventh resistor 92. The output terminal of the comparator 80 switches between logic "low" and logic "high" in response to the primary current signal rising above and falling below the the first and second current thresholds I1, 12, respectively (see FIG. 3D).

When the comparator output terminal is pulled "high," the voltage divider network 87 applies a third voltage potential V3 to the comparator non-inverting input terminal. The voltage potential applied to the comparator non-inverting input terminal is illustrated in FIG. 3E. The third voltage potential V3 corresponds to a primary current having magnitude equal to the first current threshold I1. The comparator output terminal is pulled "low" when the voltage applied to its inverting input terminal rises to the third voltage potential V3, thereby indicating that the primary current has reached the first current threshold I1. When the comparator output terminal is pulled "low," the voltage divider network 87 applies a fourth voltage potential V4, which is lower than the third voltage potential V3, to the comparator non-inverting input terminal. The fourth voltage potential V4 corresponds to a primary current equal to the second current threshold I2. The output from the comparator 80 is delivered to the MOSFET 53 through a transistor network 97.

The transistor network 87 is provided to better control switching of the MOSFET 53. The transistor network 97 includes a second npn transistor 98 and a third pnp transistor 100, both having bases connected to the comparator output terminal and being adapted to receive the comparator output signal. The second npn transistor 98 has a collector connected to the reference voltage V_{REF} and a base connected to the reference voltage R_{REF} through an eighth resistor 102. The third pnp transistor 100 has a collector connected to system ground and an emitter connected to the emitter of the second npn transistor. The base of the MOSFET 53 is connected to the junction of transistors' emitters through a ninth resistor 104 for sensing the voltage at this junction. When the comparator output goes "low," the second npn and third pnp transistors 98, 100 are respectively biased "off" and "on," thereby pulling the base of the MOSFET 53 "low." Conversely, when the comparator output goes "high," the second npn and third pnp transistors 98, 100 are respectively biased "on" and "off," thereby pulling the base of the MOSFET 53 "high."

In a first embodiment (FIG. 2A), the control logic means 78 produces the first and second switching signals in response to the primary current signal rising above and falling below the first and second current thresholds I1, I2, respectively. Whereas, in a second embodiment (FIG. 2B), the control logic means 78 produces the first switching signal in response to the primary current signal rising above the first current threshold I1. In the second embodiment, the second switching signal is produced a predetermined period of time after the production of the first switching signal.

In the first embodiment, a current flyback path is established for the primary coils 26*a–f* which allows the flyback current to flow through first current sensing resistor 64. A flyback diode 108 has an anode connected to the primary coil second terminals 32*a–f*. The cathode of the flyback diode 108 is connected to the junction of the first current sensing resistor 64 and the ignition capacitor first terminal 16*b*. Therefore, when the modulation switch 52 is open and a selector switch 34*a–f* is closed, a flyback current, as established by the charge stored in the associated primary coil 26*a–f*, flows through the first current sensing resistor 64. This current is input to the current mirror circuit 66 and, therefore, the voltage applied to the comparator inverting input terminal is responsive to the primary coil flyback current. When this voltage drops below the fourth voltage potential V4, the comparator output is pulled "high," thereby closing the modulation switch 57.

Conversely, in the second embodiment, individual flyback paths are provided for each primary coils 26*a–f* by connecting flyback diodes 108 between the first and second terminals 30*a–f*, 32*a–f* of each primary coil 26*a–f*. In this embodiment, the flyback current no longer circulates through the first current sensing resistor **64** and, thus, there is no output signal from the current mirror during this flyback period. The second embodiment was developed because CDI systems are often applied to large engines where it might be undesirable to have a flyback path through the first current sensing resistor **64** due to the amount of electrical noise generated in the wiring required to establish such a flyback path.

In the second embodiment, the second switching signal is produced a predetermined period of time after the production of the first switching signal in the second embodiment. This function is provided by the R-C network **87**. More particularly, the second embodiment also further includes a third diode **110** having an anode connected to the junction of the second pnp transistor **70** and the fifth resistor **84**. The cathode of the third diode **110** is connected to the junction of the comparator inverting input terminal and the fifth resistor **84**. When the current mirror circuit **66** produces an output current, the third diode **110** is biased "on" and the current output from the current mirror circuit **66** charges the first capacitor **86**. When the primary current reaches the first current threshold **I1**, the modulation switch **52** opens and no input signal is delivered to the current mirror circuit **66**. When this occurs, the voltage applied to the comparator inverting input terminal is controlled by the voltage across the first capacitor **86**. This voltage decays at a rate controlled by the R-C network, as would be apparent to those skilled in the art. In the second embodiment, the values of the fifth resistor **84** and the first capacitor **86** are empirically selected so that this voltage decays at the same rate as the the flyback current in the primary coils *26a–f.* Conversely, in the first embodiment, the R-C network **82** functions solely to filter electrical "noise" from the current mirror output signal. When the voltage reaches a fourth voltage potential **V4**, the output terminal of the comparator is pulled "high," and the modulation switch **52** responsively closes.

Industrial Applicability

Referring now to FIGS. 3A–E, operation of the CDI system **10** will be explained in greater detail. Initially, the modulation switch **52** is biased closed and all the selector switches **34***a–f* are biased open. At time t_o, the cylinder selector means **36** delivers a cylinder select signal (FIG. 3A) to one of the **30** selector switches **34***a–f,* thereby biasing the selector switch **34***a–f* closed. Current starts to flow through the primary coil **26***a–f* in an associated transformer **24***a–f* (FIG. 3B). The current flowing through the primary coil **26***a–f* induces a voltage potential across the spark gap **22***a–f* in an associated spark plug (FIG. 3C). At a time t_1, the voltage potential across the spark gap **22***a–f* reaches a potential V_{SP} which is sufficient to cause a spark to arc across the gap **22***a–f.* As mentioned previously, this voltage is on the order of 10–30 kV. When the spark arcs, current begins to flow through the transformer secondary coil **28***a–f.* After the initial spark, the voltage required to sustain a spark across the gap **22***a–f* is substantially reduced. This voltage is indicated by V_{SUS} and is typically on the order of 1 Kv or less.

The current in the primary coil **26***a–f* continues to rise until it reaches the first current threshold **I1** at a time t_3. When the current reaches the first current threshold **I1**, the comparator output (FIG. 3D) is pulled "low," thereby opening the modulation switch **52**. When the modulation switch **52** is open and a selector switch **34***a–f* is closed, a flyback current circulates through the flyback diode **108**. In the first embodiment, the flyback current circulates through the first current sensing resistor **64** and a voltage is applied to the inverting input of the comparator **80** in response to the magnitude of this flyback current.

Conversely, in the second embodiment, the voltage potential applied to the comparator inverting input is controlled by the R-C network **82**. When this voltage decays to the fourth voltage potential **V4**, indicating that the primary current has dropped to the second current threshold **I2**, the comparator output terminal is pulled "high." This biases the MOSFET **53** "on." The primary current then increases until it reaches the first current threshold **I1**, at which time the MOSFET **53** is again biased "off." The primary current is modulated in this manner until the selector signal goes "low" at time t_4. When this occurs, the selector switch **52** opens, thereby disconnecting the primary coil first terminal **30***a–f* and the ignition capacitor first terminal **16***a.* Thereafter the voltage across the spark gap **22***a–f* drops to a level which is not sufficient to maintain a spark.

In this manner, the charge dissipated from the ignition capacitor **18** is minimized, thereby avoiding the problems associated with past capacitor discharge ignitions. More specifically, by limiting current flow from the ignition capacitor **18**, the immediate CDI system **10** is capable of maintaining spark duration over a wide range of engine speeds while only requiring a single ignition capacitor for a plurality of engine cylinders. Other aspect, objects and advantages of this invention can be obtained from a study of the drawings, the disclosure, and the appended claims.

I claim:

1. An apparatus for controlling ignition in an internal combustion engine having N cylinders, a cylinder selector means, and a capacitor discharge ignition system, each of said cylinders including a spark plug having an associated spark gap, said capacitor discharge system being of the type having an ignition capacitor including first and second terminals and charging circuit connected to said ignition capacitor for maintaining said capacitor first terminal at a predetermined electrical potential greater than said capacitor second terminal, said cylinder selector means selectively producing cylinder select signals at desired points in time corresponding to a desired ignition sequence for said engine cylinders, said cylinder select signals being produced for a period of time corresponding to a desired spark duration in an associated cylinder, comprising:

N transformers each having a primary coil and a secondary coil, said primary coils including first and second terminals and said secondary coils being electrically being connected in parallel with a spark gap in an associated one of said N cylinders;

N selector switches each being connected between said ignition capacitor first terminal and an associated one of said primary coil first terminals, said selector switches being normally biased open and being adapted to close in response to receiving said cylinder select signals;

a modulation switch connected between said primary coil second terminals and a source of low electrical potential; and

control means for operating said modulation switch while a selector switch is closed such that the current flowing in an associated primary coil initially rises to a first current threshold sufficient to cause a spark to arc an associated spark gap and is thereafter modulated between said first current threshold and a second current threshold lower than said first current threshold to maintain said spark, and wherein said spark is maintained in this manner until said selector switch is opened.

2. An apparatus as set forth in claim **1**, wherein said control means includes:

current sensing means for sensing a current flowing through any of said primary coils and responsively producing a primary current signal;

logic means for receiving said primary current signal and producing first and second switching signals in response to said primary current signal rising above and falling below said first and second current thresholds, respectively; and

wherein said modulation switch is adapted to receive first and second signals and respectively open and close in response to said first and second signals.

3. An apparatus as set forth in claim **1** wherein said current sensing means includes a current sensing resistor connected between said ignition capacitor first terminal and said primary coil first terminals, and wherein the current flowing through said current sensing resistor is equal to the current flowing through an of said primary coils.

4. An apparatus as set forth in claim **3** including a flyback diode having an anode connected to said primary coil second terminals and a cathode connected to the junction of said ignition capacitor first terminal and said current sensing resistor, and wherein said primary current signal is responsive to an energization current which flows through said current sensing resistor when said modulation switch and one of said N selector switches are closed and to a flyback current flows which through said current sensing resistor when said modulation switch is open and one of said N selector switches are closed.

5. An apparatus as set forth in claim **4**, wherein said current sensing means includes a current mirror circuit having the current flowing through said current sensing resistor as an input and being adapted to produce an output signal having a magnitude responsive to the current flowing through said current sensing resistor.

6. An apparatus as set forth in claim **2** wherein said logic means includes a comparator adapted to receive said primary current signal, produce a first switching signal in response to said primary current rising above said first switching threshold and produce said second switching signal in response to said primary current signal falling below said second current threshold.

7. An apparatus as set forth in claim **1**, wherein said control means includes:

current sensing means for sensing the current level in any of said transformer primary coils and responsively producing a primary current signal;

logic means for receiving said primary current signal and responsively producing first and second switching signals, said first switching signal being produced in response to said primary current signal rising above a first predetermined thresholds and said second switching signal being produced a predetermined period of time after the production of said first switching signal; and

wherein said modulation switch is adapted to receive first and second signals and respectively open and close in response to said first and second signals.

8. An apparatus as set forth in claim **7** including N flyback diodes, each having an anode connected to respective primary coil second terminal and an anode connected to a respective primary coil first terminal.

9. An apparatus as set forth in claim **8** wherein said current sensing means includes a current sensing resistor connected between said ignition capacitor first terminal and said primary coil first terminals.

10. An apparatus as set forth in claim **9**, wherein said current sensing means includes a current mirror circuit having the current flowing through said current sensing resistor as an input and being adapted to produce an output signal having a magnitude responsive to the current flowing through said current sensing resistor.

11. An apparatus as set forth in claim **10** wherein said logic means includes:

an R-C network circuit having an input terminal connected to said current mirror output and being adapted to receive said current mirror output signal, an output terminal adapted to produce an output signal current signal, a resistor connected between said R-C network input and output terminals, a capacitor connected between the junction of a said resistor and said R-C network output terminal and a said source of low electrical potential, and a diode having an anode connected to the junction of said resistor and said R-C network input terminal and a cathode connected to the junction of said resistor and said R-C network output terminal; and

wherein said primary current signal is responsive to said current mirror output signal when said current mirror circuit produces an output signal and to a decay rate of said R-C network circuit in the absence of an output signal from said current mirror circuit.

12. An apparatus as set forth in claim **11** wherein the decay rate of said R-C network is responsive to a decay rate of of the flyback current through said primary coils.

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